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MICROCOPY RESOLUTION TEST CHART

Fraunhofer-Institut für Kurzzeitdynamik

Ernst-Mach-Institut

Abteilung für Ballistik

KYD 5330 HN-C1

DTIC FILE COPY

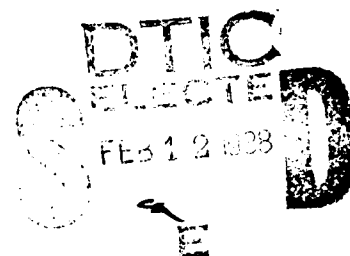# VISCOUS MODELING OF THE INTERIOR BALLISTIC CYCLE

R. Heiser

CONTRACTOR:

FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG e.V.,
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CONTRACT No. DAJA 45-86-C-0031

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First Periodic Report

April 1987 - May 1987

June - September 1987

Ernst-Mach-Institut   Eckerstrasse 4   7800 Freiburg i.Br.   Tel 0761 27141   Fraunhofer-Gesellschaft   Vorstand

1. This contract has been started on April 1, 1987. In time EMI-AFB succeeded in hiring Dr. Jürgen Garloff as a Research Associate who will work on this contract by a full time job. He has a very good background in numerical mathematics above all in solving particular sets of linear equations as they are found, for example, in computational fluid dynamics by applying implicit finite difference methods. Since he was never involved in ballistic problems he has been mainly busy with becoming familiar with the objective of the contract during this period. This concerned the physical subject as well as its way of mathematical approach.

2. The latest version of the DELTA code as it existed at the BRL at the end of 1984 was successfully installed on the EMI-AFB computer. This means that we abandoned the CDC Update format and made this modified version operational on our VAX computer. As no significant modifications of this code had been reported to us since 1984, we assume that this code version is the newest one with respect to the physical modeling and its numerical solution of the viscous modeling of the interior ballistic flow.

3. One of the first objectives of the contract is dealing with the turbulent modeling of the interior ballistic flow. Therefore, I visited a lecture course on Modeling of Turbulence at the von Karman Institute for Fluid Dynamics at Rhode-Saint-Genèse, Belgium. This course gave an overview on the state-of-the-art in the mathematical modeling of turbulent flows.
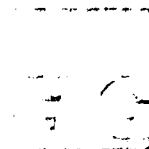
Weil am Rhein, 26 May 1987

R. Heiser

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Abteilung für Ballistik

VISCOUS MODELING OF THE INTERIOR BALLISTIC CYCLE

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Second Periodic Report

June 1987 - September 1987

The research reported in this document has been made
possible through the support and sponsorship of the
U. S. Government through its European Research Office
of the U. S. Army. ~~This report is intended only for
the internal management use of the Contractor and the
U. S. Government~~.

The latest version of the DELTA code as it was installed on
the EMI-AFB VAX computer was used to run several test cases
for the laminar type of flow. The results agreed with those
computed at the Ballistic Research Laboratory such that we
assumed that the installation of DELTA was successful. There-
after the investigations of the turbulent flow have been started.
In a first step the implementation of algebraic mixing length
turbulence models was resumed. Two different algebraic turbulence
models were considered and incorporated into the DELTA code,
e.g., the Cebeci-Smith-Mosinski Model and the Baldwin-Lomax
Model. To display the results obtained, comprehensive graphics
software was developed.

During the second period two meetings took place:

- On June 1, 1987, R. Heiser visited the Department of Mechani-
  cal Engineering of the Imperial College of Science and
  Technology, London, UK, to discuss with J. H. Whitelaw and
  his co-workers how they can support our modeling efforts by
  experiments with their gun simulators.

- J. Garloff visited the Ballistic Research Laboratory, Aberdeen
  Proving Ground, MD, on September 3 and 4, 1987, to report the
  progress made by our ongoing activities.

Numerical Results

At present, two algebraic turbulence models are considered and
coded in DELTA: the Cebeci-Smith-Mosinski Model and the Baldwin-
Lomax Model. Computational results were obtained for the so-
called Lagrange gun, i.e., the simulation of a pure gas expan-
sion flow behind a projectile inside of a constant cross-section
tube. The tube is closed at one end by a stationary surface, and
at the other end by a movable flat based projectile. The initial
states of the gas are uniform and quiescent. The numerical
results enclosed refer to a 20-mm caliber tube assuming an
initial pressure of 300 MPa and an initial temperature of
3000 K. Figures 1 to 12 show the axial and radial flow velocity,

temperature, and pressure computed by using the Baldwin-Lomax Model at the time steps 100, 200, and 300. In comparison, the application of the Cebeci-Smith-Mosinski Model results in stronger oscillations in the computed quantities especially for high numbers of time steps. Special emphasis was put on the computation of the boundary layer. Figures Nos. 13 to 15 show the growing of the boundary layer thickness and the boundary layer displacement thickness for time steps 100, 200, and 300 computed by using the Baldwin-Lomax Model. The boundary layer thickness and boundary layer displacement thickness computed by using the Cebeci-Smith-Mosinski Model coincide in general after about 250 time steps. However, this model gives again oscillations in both quantities.

We have also simulated the transition of laminar to turbulent flow. Our computations show that there is no significant difference to the results obtained under the assumption of a purely turbulent flow.

The oscillations obtained by using both algebraic turbulence models are not satisfactory since in the laminar case no oscillations were observed. Therefore, we are going to incorporate into the code a nonalgebraic turbulence model, e.g., the k-ε-Model (see Section on future work).

Up to now our Institute does not have available the graphics software for running the pre- and post-processors of DELTA. To display the numerical results, software for 2-D and 3-D plots was developed. Also a plot of the projectile velocity history is now available, see Figure 16.

Future Work

We have just obtained a series of experimental data on boundary
layers measured by J. H. Whitelaw and his co-workers [1,2].
These results have been obtained by experiments with low pres-
sure gun simulators. We will run the DELTA code for computing
the flow in the simulator and compare the results with the
experimental data.

At present, nonalgebraic turbulence models, e.g., the k-ε-Model
are considered and will be coded. To treat also heat transfer,
J. Garloff will attend a lecture series entitled "Numerical
Methods of Fluid Dynamics and Heat Transfer" to be held at
the University of Erlangen-Nürnberg, FRG, at the end of
October 1987. In this course, one main objective will be the
presentation and demonstration of various codes for the com-
putation of turbulence and heat transfer problems.

We did not succeed so far to find a black box solver suitable
for our purposes. Available codes considered so far suffer from
being presently designed only for incompressible flows (e.g.,
MODULEF, Multigrid Solvers) or their conversion to our system
would require extensive time, effort, and a commitment of
programmer assistance for successful transfer (this applies
to the codes from Lawrence Livermore National Laboratory).

W. Schönauer from the University of Karlsruhe, FRG, is designing
a code named FIDISOL for treating also problems of compressible
unsteady flows at high Reynolds numbers. But his work is still
under development and the code can not be expected to be
available for us before 1/2 to 1 year.

References

[1]   Bicen, A.F., Khezzar, L., Whitelaw, J.H., "Subsonic Single-
      Phase Flow in a Gun Simulator", Imperial College of Science
      and Technology, Mechanical Engineering Department, London,
      UK, Rep. FS/86/03, April 1986

[2]   Bicen, A.F., Khezzar, L., Whitelaw, J.H., "Subsonic Single-
      and Two-Phase Flow Characteristics of a Gun Simulator",
      Imperial College of Science and Technology, Mechanical
      Engineering Department, London, UK, Rep. FS/86/43, Sept. 1986

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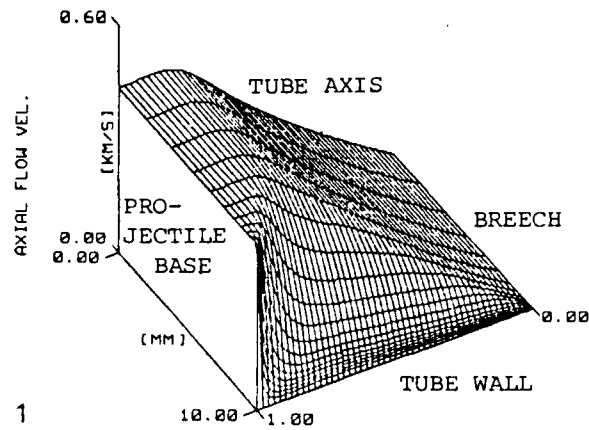
Figure 1

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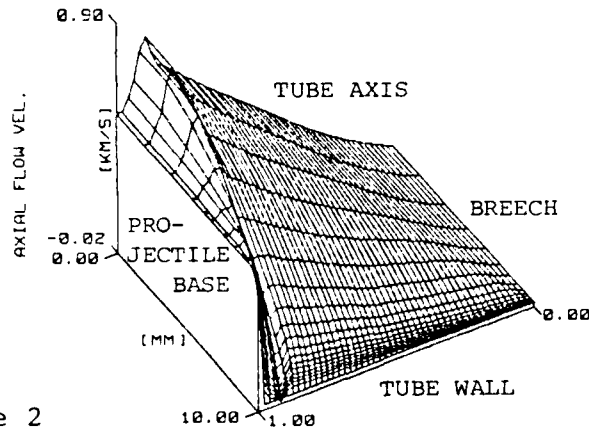
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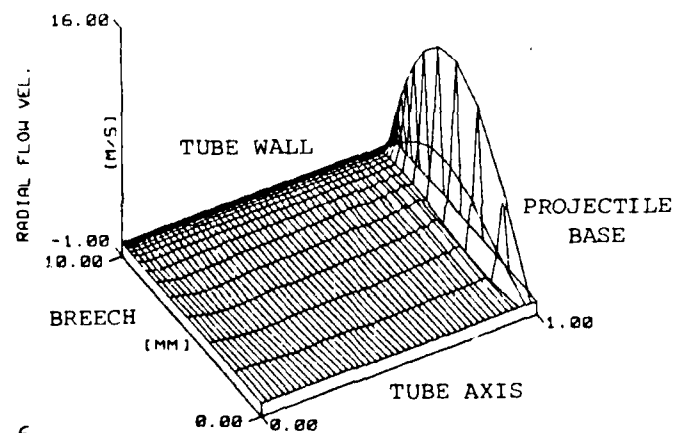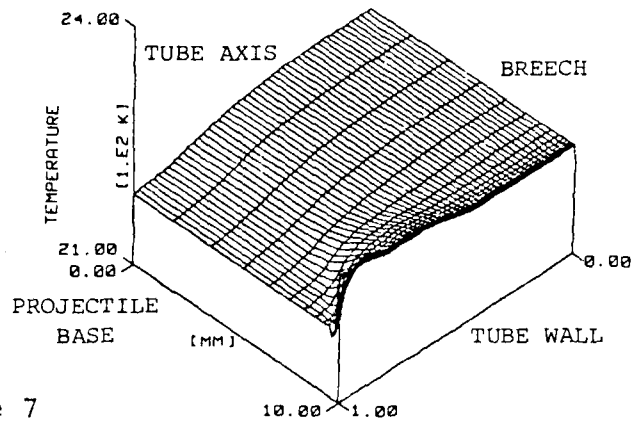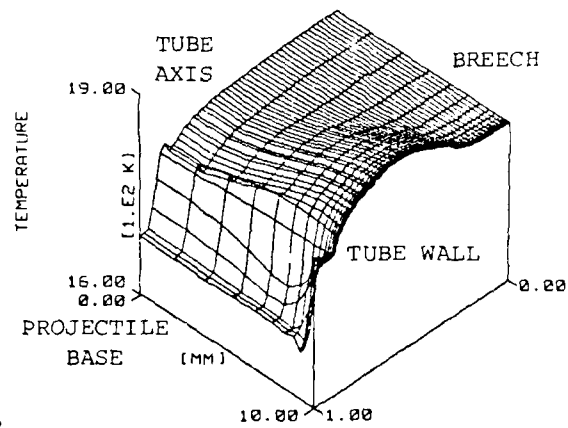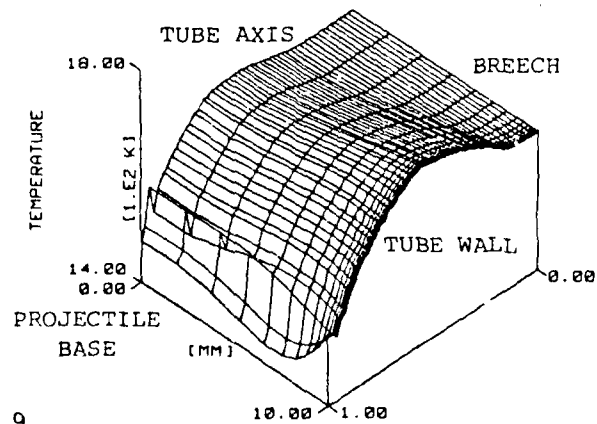PROJ. DISPLACEMENT = 1.510 [M] PROJ. VEL. = 572.5 [M/S]
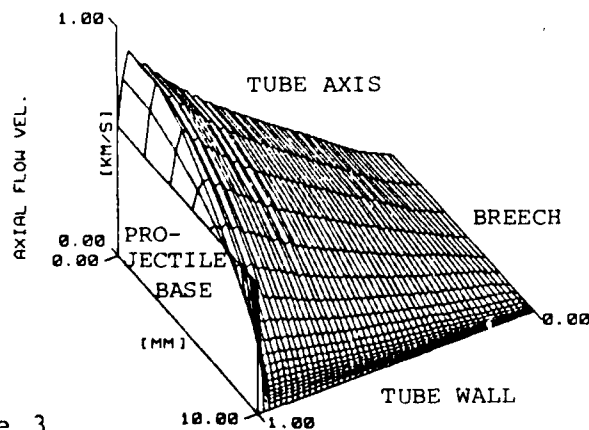
Figure 3

TIME-STEP = 100   TIME = 1.000 [MS]
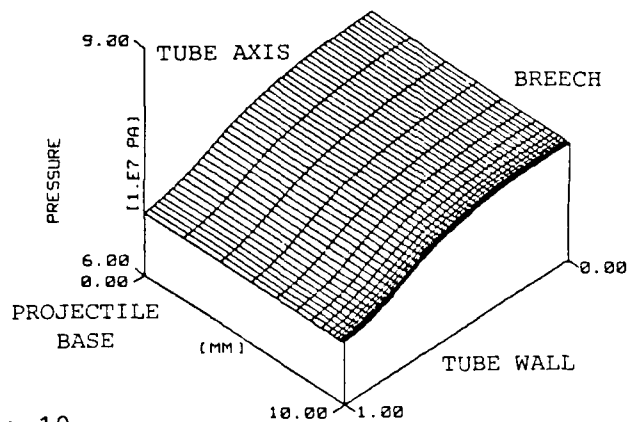PROJ. DISPLACEMENT = 0.451 [M]   PROJ. VEL. = 440.8 [M/S]
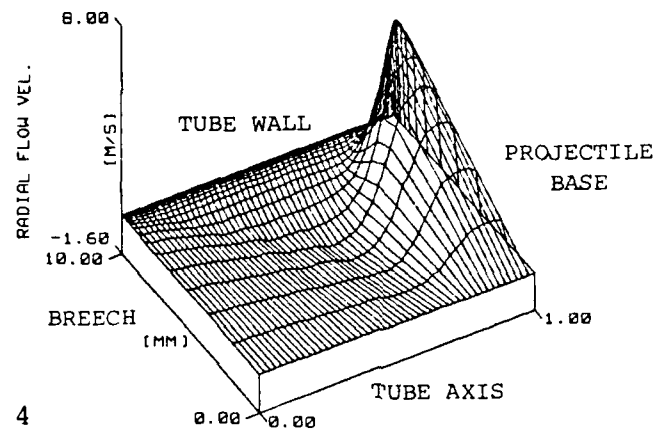
Figure 4

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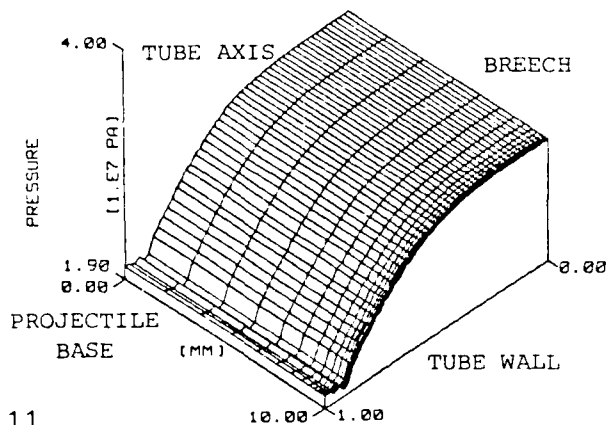PROJ. DISPLACEMENT = 0.951 [M]   PROJ. VEL. = 540.5 [M/S]
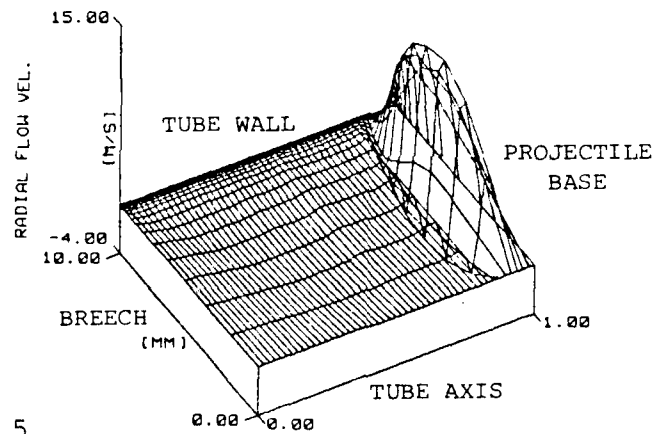
Figure 5

TIME-STEP = 300   TIME = 3.000 [MS]
PROJ. DISPLACEMENT = 1.510 [M]   PROJ. VEL. = 572.5 [M/S]

Figure 6

TIME-STEP • 100 TIME • 1.000 (MS)
PROJ. DISPLACEMENT • 0.451 (M) PROJ. VEL. • 440.8 (M/S)

Figure 7

TIME-STEP • 200 TIME • 2.000 (MS)
PROJ. DISPLACEMENT • 0.951 (M) PROJ. VEL. • 540.5 (M/S)

Figure 8

TIME-STEP • 300 TIME • 3.000 (MS)
PROJ. DISPLACEMENT • 1.510 (M) PROJ. VEL. • 572.5 (M/S)

Figure 9

TIME-STEP •   100   TIME • 1.000 [MS]
PROJ. DISPLACEMENT • 0.451 [M]   PROJ. VEL. • 440.8 [M/S]

Figure 10

TIME-STEP •   200   TIME • 2.000 [MS]
PROJ. DISPLACEMENT • 0.951 [M]   PROJ. VEL. • 540.5 [M/S]

Figure 11

TIME-STEP •   300   TIME • 3.000 [MS]
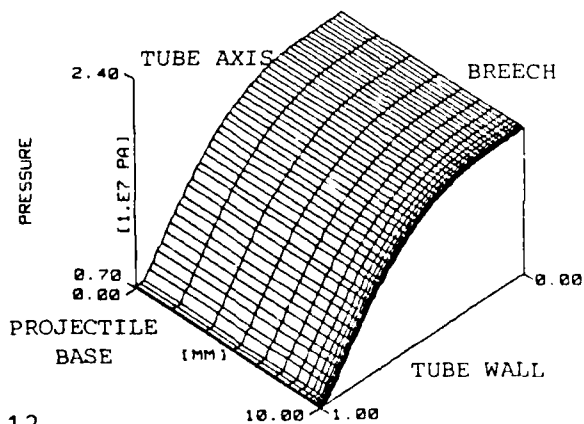PROJ. DISPLACEMENT • 1.510 [M]   PROJ. VEL. • 572.5 [M/S]

Figure 12

TIME-STEP = 100   TIME = 1.000 [MS]
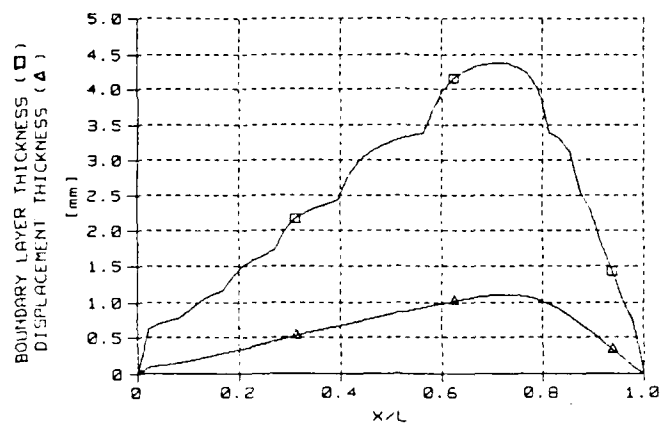PROJ. DISPLACEMENT = 0.451 [M]   PROJ. VEL. = 440.8 [M/S]

Figure 13

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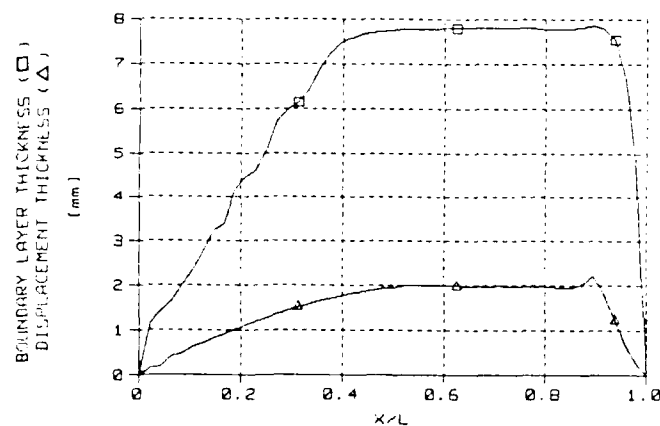PROJ. DISPLACEMENT = 0.951 [M]   PROJ. VEL. = 540.5 [M/S]

Figure 14

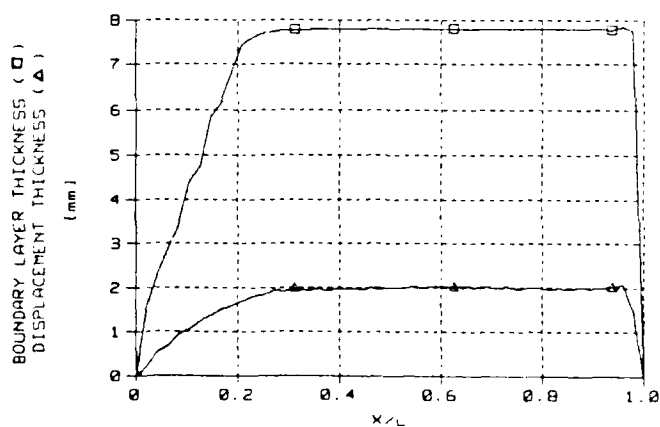TIME-STEP = 300   TIME = 3.000 [MS]
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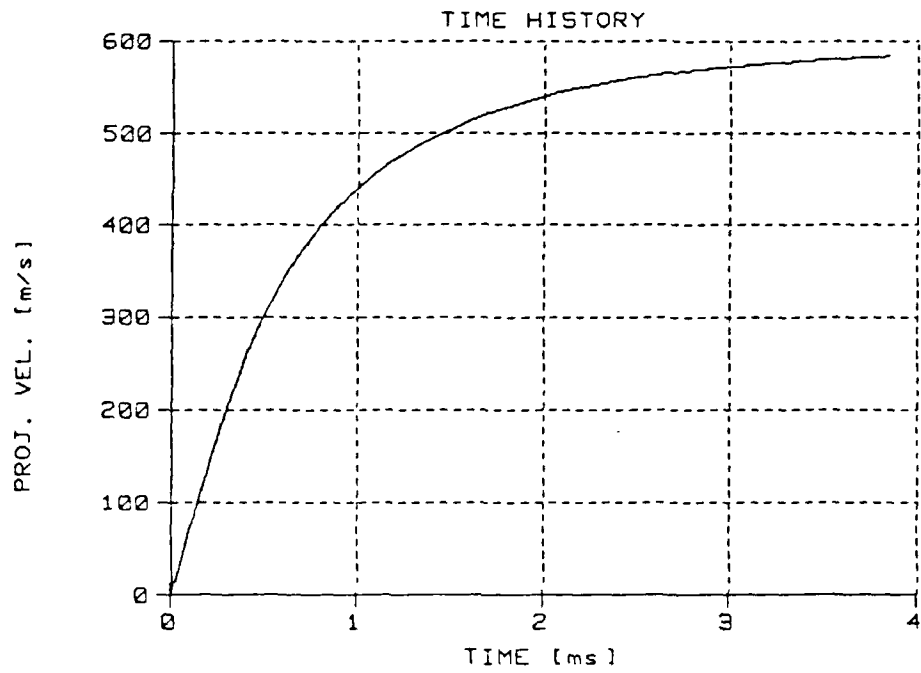
Figure 15

Figure 16

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